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Environmental Restoration Project
Standard Operating Procedure

for:

Slug Tests

Los Alamos

NATIONAL LABORATORY

Los Alamos, New Mexico 87545

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Slug Tests

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Slug Tests

Standard Operating Procedure Title

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the process for determining saturated hydraulic conductivity under in situ conditions by the slug test withdrawal method of analysis for the Los Alamos National Laboratory (Laboratory) ER Project.

2.0 SCOPE

This SOP is a mandatory document and shall be implemented by all ER Project participants when performing slug tests for the ER Project.

3.0 TRAINING

- 3.1 All users of this SOP are trained by reading the procedure, and the training is documented in accordance with QP-2.2.
- 3.2 The Field Team Leader (FTL) shall monitor the proper implementation of this procedure and ensure that relevant team members have completed all applicable training assignments in accordance with QP-2.2.

4.0 DEFINITIONS

Note: A glossary of definitions can be located on the ER Project internal homepage <http://erinternal.lanl.gov>.

- 4.1 Hydraulic conductivity — The rate of fluid flow in gallons per day through a cross section of one square foot (gpd/ft²) of a permeable medium under a unit hydraulic gradient at the prevailing temperature or at 16°C. It is a function of both the media and of the fluid flowing through it. Also known as the coefficient of permeability or Meinzer unit.
- 4.2 Site-Specific Health and Safety Plan (SSHASP)—A health and safety plan that is specific to a site or ER-related field activity that has been approved by an ER health and safety representative. This document contains information specific to the project including scope of work, relevant history, descriptions of hazards by activity associated with the project site(s), and techniques for

exposure mitigation (e.g., personal protective equipment [PPE]) and hazard mitigation.

- 4.3 Storage coefficient— The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (dimensionless).
- 4.4 Transmissivity—The flow rate of water in a cross section of saturated material having the dimensions unit width and total thickness as height, under a unit hydraulic gradient. Also, hydraulic conductivity times thickness of the material.

5.0 BACKGROUND AND PRECAUTIONS

Note: This SOP is to be used in conjunction with an approved SSHASP. Also, consult the SSHASP for information on and use of all PPE.

- 5.1 The slug test measures the rate of water-level recovery in a well over time in response to the injection or withdrawal of a mass (slug) beneath the groundwater surface. The slug can be a quantity of water or a solid of known volume. Hydraulic conductivity in the immediate vicinity of the well can be determined by measuring water-level versus time data after the slug is added or removed. Refer to the site-specific work plan for more information on the scope of work, a description of slug testing activities, and the locations of the wells that are to be tested.
- 5.2 First, a solid slug is inserted to a level beneath the groundwater surface and the water level is allowed to reach equilibrium. Then the slug is removed and the rise in water level is measured with time. Alternatively, a slug of water is injected or withdrawn and water-level response monitored.
- 5.3 The primary advantages of using slug tests to estimate conductivities are:
- estimates can be made in situ and the errors incurred in the laboratory testing of disturbed samples can be avoided.
 - tests can be performed quickly at relatively low costs because a pumping well and observation wells are not required.
 - the hydraulic conductivity of small, discrete portions of a saturated medium can be estimated (e.g., sand layers in a clay).
- 5.4 Limitations of slug testing include:
- only the hydraulic conductivity of the saturated material immediately surrounding the well is estimated, which may not be representative of it over a larger area.

- certain assumptions are made in the analysis process; if the assumptions are inappropriate for the geologic conditions at the site, the slug test data are invalid.
 - the storage coefficient, S , usually cannot be determined
 - data sufficient for analysis may not be collected if the hydraulic conductivity is relatively high.
- 5.5 The time required for a slug test is a function of the volume of the slug, the hydraulic conductivity of the formation, and the type of well completion. The slug volume should be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions. The length of the test may range from less than a minute to several hours.
- 5.6 If the well is to be used for monitoring, take precautions so contamination is not introduced by equipment placed in the well.
- 5.6.1 If water is added to the monitoring well, it must be obtained from an uncontaminated source and transported in a clean container.
- 5.6.2 Clean bailers or measuring devices before the test in accordance with SOP-01.08, Field Decontamination of Drilling and Sampling Equipment.
- 5.7 Conduct slug tests on relatively undisturbed wells. If a test is conducted on a well that has recently been pumped for water-sampling purposes, the measured water level must be within 0.1 ft of the static water level at the wells.
- Note:** The exact dimensions of the borehole, casing, and filter must be recorded for accurate analysis of the slug test data.
- 5.8 Site workers preparing for field operations should read and understand the procedures outlined in the SSHASP for the particular health and safety equipment to be used.

6.0 RESPONSIBLE PERSONNEL

The following personnel are responsible for activities identified in this SOP.

- 6.1 Focus Area Leader
- 6.2 Team Leader
- 6.3 Quality Program Project Leader
- 6.4 ER Project participants involved in the testing

7.0 EQUIPMENT

A checklist of suggested equipment and supplies needed to implement this procedure is provided in Attachment A.

- 7.1 *Pressure Transducer*— A device which senses pressure variations and converts it to an electrical signal for transmission to another device (a receiver) for processing or decision making. A number of pressure transducers are available on the market. The operator must consult the manufacturer's specifications on calibration, operation, maintenance and chemical compatibility with the contaminants at the site. All field personnel performing slug tests using pressure transducers must review SOP-07.01, Pressure Transducer, prior to starting work.
- 7.2 *Electric Water Level Meter*— A flat graduated tape is attached to a stainless steel probe containing an electrode, which emits an audible and visible signal when contact with water is made.

8.0 PROCEDURE

- Note:** Subcontractors performing work under the ER Project's quality program may follow this SOP for collecting slug test data. Subcontractor's own procedures may be used provided that the substitute procedures meet the requirements prescribed by the ER Project Quality Management Plan, and have been approved by the ER Project's Quality Program Project Leader (QPPL) before starting the activities.
- Note:** ER Project personnel may produce paper copies of this procedure printed from the controlled-document electronic file located at website http://erinternal.lanl.gov/home_links/Library_proc.htm. However, it is their responsibility to ensure that they are properly trained and are utilizing the current version of this procedure. The author may be contacted if text is unclear.
- Note:** Deviations from SOPs are made in accordance with QP-4.2, Standard Operating Procedure Development. Procedure deviations are documented in accordance with QP-5.7, Notebook Documentation for Environmental Restoration Technical Activities.
- 8.1 The following general procedures should be used to collect and report slug test data. The procedures required for a particular slug test may vary slightly from those described, depending on site-specific conditions. Modifications to the test procedures will be contained in the site-specific work plan.

- 8.2 Procedures for conducting the slug test with a pressure transducer and data logger, as well as a water-level probe, are described below. Be sure to complete all data-collection forms.
- 8.3 Slug Test with Pressure Transducer and Data Logger
- 8.3.1 Before beginning the slug test, enter the required information into the electronic data logger in accordance with the manufacturers instructions. It is important to consult the operations manual for the proper data-entry sequence as different models require different data entry procedures. See SOP-07.01 for instructions pertaining to calibration and use of a pressure transducers.
 - 8.3.2 When using an electronic data logger and pressure transducer to perform the slug test, store all data internally; and also on computer diskettes or on tape. The information should be transferred directly to the appropriate computer for analysis as soon as practical after the test is completed. Maintain a computer printout of the data in the project files as documentation.
 - 8.3.3 Determine the static water level in the well; measure the depth to water periodically for several minutes to several hours, and taking the average of the readings (see SOP-07.02). Record information on the Water-Level Elevation Data Sheet found in SOP-07.02 (Attachment B). Additional information should be recorded on the Daily Activity log in SOP-01.04 (Attachment E).
 - 8.3.4 Install the transducer and cable in the well below the estimated target drawdown depth. Be sure the depth of submergence is within the design range stamped on the transducer. Tape the transducer cable to the well to hold the transducer at a constant depth.
 - 8.3.5 After connecting the transducer cable to the electronic data logger, enter the initial water level and transducer design range into the recording device according to the manufacturer's operating instructions. Record the initial water level on the recording device.
 - 8.3.6 Smoothly lower the slug or bailer into the well. Observe the transducer readout to detect where the slug contacts the water.
 - 8.3.7 Allow the water level to stabilize (within 0.1 ft) and remove the cylinder or bailer. Remove the slug or volume as quickly and smoothly as possible because the analysis assumes that an instantaneous change in volume is created in the well.
 - 8.3.8 Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of

readings have been made to clearly show a trend on a plot of water-level recovery versus the logarithm of time.

8.4 Slug Test with Electric Water Level Meter

Note: This method should only be used if an electronic data recorder cannot be obtained. This method cannot be used for saturated zones with high hydraulic conductivities because stabilization of groundwater will occur rapidly. If the slug test data are collected and recorded manually, record observations on the Slug Test Data form (Attachment B) in accordance with the completion instructions.

8.4.1 Determine the static water level in the well. Measure the depth to water periodically for several minutes and take the average of the readings according to the instructions in SOP-07.02. Record results on the Water-Level Elevation Data Sheet.

Note: In order to accurately measure water-level changes, it is important to take the measurements rapidly.

8.4.2 Smoothly lower the slug or bailer into the well. The depth where the top of the slug contacts the water can be estimated by marking the depth to water found in Section 6.4.1 onto the slug line.

8.4.3 Measure and record the depth to water and time of each reading. The moment when the volume is removed is time zero. Depths should be measured to the nearest one hundredth of a foot. The number of depth/time measurements necessary to complete the test varies.

8.4.4 Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a plot of water-level recovery versus the logarithm of time.

8.5 Straddle-Packer/Injection Test with Transducer and Data Logger

Note: This method is used when the well is completed with multiple screens that must be isolated for testing. The straddle-packer/injection assembly is available from the Field Support Facility.

8.5.1 Insert straddle packer/injection assembly opposite screen of interest.

8.5.2 Determine the static water level in the well; measure the depth to water periodically for several minutes to several hours, and taking the average of the readings (see SOP-07.02). Record information on the Water-Level Elevation Data Sheet found in SOP-07.02 (Attachment B). Additional information should be recorded on the Daily Activity log in SOP-01.04 (Attachment E).

- 8.5.3 Install the transducer and cable in the well below the estimated target drawdown depth. Be sure the depth of submergence is within the design range stamped on the transducer. Tape the transducer cable to the well to hold the transducer at a constant depth.
- 8.5.4 After connecting the transducer cable to the electronic data logger, enter the initial water level and transducer design range into the recording device according to the manufacturer's operating instructions. Record the initial water level on the recording device.
- 8.5.5 Before beginning the slug test, enter the required information into the electronic data logger in accordance with the manufacturers instructions. It is important to consult the operations manual for the proper data-entry sequence as different models require different data entry procedures. See SOP-07.01 for instructions pertaining to calibration and use of a pressure transducers.
- 8.5.6 Fill large open stock tank with potable water.
- 8.5.7 Connect flow meter on inflow side of pump on drill rig.
- 8.5.8 Connect hose to open end of flow meter and submerge other end in stock tank.
- 8.5.9 Connect another hose to the outflow end of pump on drill rig.
- 8.5.10 With pump on, adjust the flow to reasonable rate before starting the test (direct discharge back into stock tank).
- 8.5.11 Read and record totalizer on flow meter (gal).
- 8.5.12 Direct discharge down rod connected to straddle-packer assembly and record the time injection started.
- 8.5.13 After a short time interval, halt injection by removing hose and placing it in stock tank.
- 8.5.14 Record time and totalizer on flow meter (gal).
- 8.5.15 Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a plot of water-level recovery versus the logarithm of time.
- 8.5.16 Be sure data sheet is filled in completely (Attachment C).
- 8.6 Post-operation Activities
 - 8.6.1 Decontaminate the downhole equipment according to ER-SOP-1.08. Cut off contaminated portions of rope and dispose of them in accordance with ER-SOP-1.06.

8.6.2 If you used an electronic data logger, proceed as follows:

- stop the logging sequence,
- download the data to a computer, print the data, file them on a floppy disk, and
- save the memory and disconnect the battery at the end of the day's activities.

8.7 Check all data-collection forms for completeness.

8.8 Lessons Learned

8.9 During the performance of work, ER Project personnel shall identify, document and submit lessons learned in accordance with QP-3.2, Lessons Learned. This QP can be located at website http://erinternal.lanl.gov/home_links/Library_proc.htm.

9.0 REFERENCES

ER Project personnel may locate the ER Project Quality Management Plan/ER Project QP requirements crosswalk at http://erinternal.lanl.gov/home_links/Library_proc.htm.

The following documents have been cited within this procedure.

QP-2.2, Personnel Orientation and Training

QP-3.2, Lessons Learned

QP-4.2, Standard Operating Procedure Development

QP-4.3, Records Management

QP-5.7, Notebook Documentation for Environmental Restoration Technical Activities

SOP-01.04, Sample Control and Field Documentation

SOP-01.06, Management of Environmental Restoration Project Wastes

SOP-01.08, Field Decontamination of Drilling and Sampling Equipment

SOP-07.01, Pressure Transducers

SOP-07.02, Fluid Level Measurements

10.0 RECORDS

The FTL is responsible for submitting the following records (processed in accordance with QP-4.3) to the Records Processing Facility.

- 10.1 A completed Slug Test Data form.
- 10.2 A completed Water-Level Elevation Data Sheet
- 10.3 Daily Activity Log that contains any deviations, calibration data, and any additional comments.

11.0 ATTACHMENTS

ER project personnel may use documentation formats different from those attached in this SOP—provided the substitute forms include the information required in the official forms.

Attachment A: Equipment and Supplies Checklist for Slug Tests (1 page) located at <http://erinternal.lanl.gov/Quality/forms.htm>.

Attachment B: Slug Test Data (form and completion instructions) (2 pages) located at <http://erinternal.lanl.gov/Quality/forms.htm>.

Attachment C: Straddle-Packer/Injection Test Data Sheet (and instructions) (3 sheets) located at <http://erinternal.lanl.gov/Quality/forms.htm>.

[Using a token card, click here to record "self-study" training to this procedure.](#)

If you do not possess a token card or encounter problems, contact the RRES-ECR training specialist.

Equipment and Supplies Checklist Well Slug Tests

- _____ Water pressure transducers, if appropriate
- _____ Electronic Data logger
- _____ Electric water level indicator if transducer method is not used
- _____ Manufacturer's operating manuals for equipment selected above
- _____ Weighted tapes with plover (plumb bob)
- _____ Steel tape (graduated in hundredths of a foot)
- _____ Blue surveyor's chalk
- _____ Teflon or stainless steel bailer of a known volume
- _____ Stopwatch or watch with a second hand
- _____ Tape measure (graduated in tenths of a foot)
- _____ Semi log graph paper (if required)
- _____ Straight edge
- _____ Calculator
- _____ Appropriate reference material
- _____ Duct tape
- _____ Indelible dark-ink pens
- _____ Daily Activity Logs
- _____ Groundwater Elevation Forms
- _____ Slug Test Data forms
- _____ Any PPE listed or required in the SSHASP
- _____ Five gallon bucket
- _____ Any additional supplies listed in associated procedures, as needed
- _____
- _____
- _____
- _____
- _____

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<h2 style="margin: 0;">Slug Test Data</h2>					
Location _____ Geologic Unit _____ Well Number _____ Sheet _____ of _____					
Field Team Member Signature _____ <small>(Print name and title, then sign)</small>					
Test Method: _____ Slug Injection or _____ Slug Withdrawal Slug Dimensions or volume _____					
Well Construction Details (attach diagram): _____					
Test Started _____ Test Stopped _____ Test ID _____					
Method of Water-Level Measurement: _____					
Comments: _____ _____ _____					
Time of Measurement	Elapsed Time (minutes)	Depth to Water (feet)	Time of Measurement	Elapsed Time (minutes)	Depth to Water (feet)
? Check here if continued on the back of this sheet.					
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Instructions for Completing a Slug Test Data Sheet

Use an indelible dark-ink pen. Make an entry in each blank. For entry blanks for which no data are obtained (except in Comments section), enter “UNK” for unknown, “N/A” for not applicable, or “ND” for not done, as appropriate. To change an entry, draw a single line through it, add the correct information above it, and date and initial the change. For all forms, complete the following information:

Header Information:

1. Location — Record Tech Area, canyon, well field, as appropriate.
2. Geologic Unit — Note stratigraphic unit behind screen tested.
3. Well Number — Record the well designation number.
4. Sheet Number — Number all the sheets that are used for this activity, by day or by some practical unit.
5. Field Team Member Identification — Print your name and position title, then sign.

Slug Test Parameters:

1. Test Method — Record whether the slug device is injected or withdrawn (pulled out) from the monitor well.
2. Slug Dimensions — The slug and/or bailer dimensions or water volume must be known in order to perform calculations properly.
3. Well Construction Details — The well screen length (especially of openings), filter pack length, casing diameter and borehole diameter must be known, at a minimum, to perform calculations. Attach diagram of well design.
4. Test Started — Record clock time slug inserted or withdrawn
5. Test Stopped — Record clock time monitoring halted.
6. Test ID — For data logger file if transducer used.
7. Method of Water-Level Measurement — Record the type of instrument used to measure water level.
8. Comments — Record any relevant weather and all other conditions pertinent to the sample collection in this section.

Slug Test Data:

1. Time of Measurement — Record clock time that reading was made in the following formats: DD-MM-YY (e.g., 01-Jan-91) and the 24 hour clock time (0837 for 8:37 a.m. and 1912 for 7:12 p.m.)
2. Elapsed Time (min.) — Record, in minutes, the cumulative time readings from the beginning of the test (time zero) to the end of the test.
3. Depth to Water (ft)— Record the depth to water measured in hundredths of feet.

STRADDLE-PACKER/INJECTION TEST DATA SHEET

Well _____ Screen no. _____ Open interval _____ ft Geologic unit _____
 Test ID _____ Test Date _____ Conducted by _____
 Borehole diameter _____ inches Screen type _____ Screen ID _____ inches

Packer Assembly

Upper packer length _____ ft Bottom set at depth of _____ ft
 Flow pipe length _____ ft Packer pressure _____ psi
 Lower packer length _____ ft Top set at depth of _____ ft

Water Level (WL)

Measuring point (MP) _____ Stick-up _____ ft

WL method _____ Measured by _____

WL Depth (ft)	Time	WL Depth (ft)	Time	WL Depth (ft)	Time
---------------	------	---------------	------	---------------	------

_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Static WL depth below MP _____ ft Date _____ Time _____

Ground-surface elevation _____ ft MP elevation _____ ft

MP "stickup" + _____ ft Static WL depth - _____ ft

MP elevation = _____ ft **Level reference** = _____ ft

Transducer rating _____ psi Safe transducer depth _____ ft T. Placement _____ ft

Flow Rate (continue on back if needed)

Volume (gal)	Time (min)	Flow Rate (gpm)	Volume (gal)	Time (min)	Flow Rate (gpm)
--------------	------------	-----------------	--------------	------------	-----------------

_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Flow-rate method _____ **Average flow rate** _____ gpm

Test

Test started _____ Injection Stopped _____ Test stopped _____ Length of test _____

Flow meter at start _____ gal Flow meter at stop _____ gal Volume injected _____ gal

Comments:

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Instructions for Completing a Straddle-Packer/Injection Test Data Sheet

Use an indelible dark-ink pen. Make an entry in each blank. For entry blanks for which no data are obtained (except in Comments section), enter "UNK" for unknown, "NA" for not applicable, or "ND" for not done, as appropriate. To change an entry, draw a single line through it, add the correct information above it and date and initial the change. For all forms, complete the following information.

Header Information

1. Well – Record the number of the well tested
2. Screen – Record number of the screen tested, counting from the top down
3. Open Interval – Record the length of openings on the screen (ft)
4. Geologic Unit – Record the stratigraphic unit the screen is open to
5. Test ID – Label for data logger file; from well and screen number: R-22-2
6. Test Date – Record month, day, year of test
7. Conducted by – *Print* name of main person performing test
8. Borehole Diameter – Enter size (inches)
9. Screen Type – Tell kind of screen (wire-wrapped, louvered, etc)
10. Screen ID – Enter inside diameter of screen (inches)

Packer Assembly

1. Upper Packer Length – Enter length (ft)
2. Bottom Set At – Enter depth of base of upper packer (ft)
3. Flow Pipe Length – Enter length of perforated pipe between packers (ft); do not include length of any blank rod between perforated pipe and packers.
4. Packer Pressure – Record pressure from gauge on tank (psi)
5. Lower Packer Length – Enter length (ft)
6. Top Set At – Enter depth of top of lower packer (ft)

Water Level

1. Measuring Point – Describe what was used

2. Stick-Up – Give height of measuring point above ground surface (ft)
3. WL Method – Tell how water level was measured (device used)
4. Measured by – Identify who was taking water-level readings
5. WL Depth/Time – Record all water-level readings and times made
6. Static WL Depth below MP – Give final water-level reading, date and time
7. Ground-Surface Elevation – Record site elevation; indicate if estimated
8. MP Stick-up – same as item 2 above
9. MP Elevation – sum of 7 and 8
10. MP Elevation – same as 9
11. Static WL Depth – same as 6
12. Level Reference – For data logger software; 10 minus 11
13. Transducer Rating – Record that specified on instrument (psi)
14. Safe Transducer Depth – value that would not exceed rating (ft)
15. Placement – Record depth at which transducer was placed

Flow Rate

1. Volume/Time/Flow rate – Volume of water pumped (gal) during specified time interval (min) and the flow rate indicated (gpm); *calculate frequently so variability of flow rate can be determined*
2. Flow-Rate Method – Tell how rate was determined (volume per discrete time interval or time per discrete flow volume)
3. Average Flow Rate – Give mean of the various determinations

Test

1. Test Started – Record clock time when water first injected
2. Injection Stopped – Record time when injection halted
3. Test Stopped – Record clock time when monitoring WL halted
4. Length of Test – Record difference between 1 and 3
5. Flow Meter at Start – Record totalizer value on meter when injection begins
6. Flow Meter at Stop – Record totalizer value on meter when injection halted
7. Volume Injected – Record Difference between 6 and 5